PB83-195719

Trace Metal Chemistry of the Waters of Lake Huron

Michigan Univ., Ann Arbor

Prepared for

Environmental Protection Agency
Chicago, IL

Dec 82

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. Publication 21 Great Lakes Research Div.	2.
3. RECIPIENT'S ACCESSION NO. PB83 195719	
4. TITLE AND SUBTITLE Trace Metal Chemistry of the Waters of Lake Huron	5. REPORT DATE December 1982
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Ronald Rossmann	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Great Lakes Research Division University of Michigan Ann Arbor, Michigan 48109	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. Grant No. R005546-0-10 and R005546-0-11
12. SPONSORING AGENCY NAME AND ADDRESS Great Lakes National Program Office (GLNPO) USEPA, Region V, 536 S. Clark Street Chicago, ILL 60605	13. TYPE OF REPORT AND PERIOD COVERED Final
	14. SPONSORING AGENCY CODE 5GLNPO USEPA, Region V

15. SUPPLEMENTARY NOTES

Project Officer - David C. Rockwell

16. ABSTRACT

To provide information on total and dissolved trace metals, Lake Huron waters were analyzed for iron, cadmium, copper, chromium, lead, nickel, zinc, manganese, mercury, arsenic, aluminum, silver, vanadium, and selenium concentrations. Median total, dissolved, and particulate concentrations in ug/L for each metal are:4,8,.80, and 6.4 for iron; .015,0, and .012 for cadmium; .40, .28, and .12 for copper; .13,.11, and .017 for chromium; .022, .0087, and .041 for lead; .54, .49, and .034 for nickel; .29, .17, and .33 for zinc; .67, .28, and .58 for manganese; .011, .0042, and not measured for mercury; .21, .22 and .0086 for arsenic; 8.8, 3.1, and 15 for aluminum; .0090, .0058, and .0013 for silver; .22, .24, and .014 for vanadium; and .48, .48, and 0 for selenium, respectively.

For each metal, the total does necessarily equal the dissolved plus particulate fractions. Differences appear to be an artifact of analytical technique. The percentage of metal in particulate matter for each element is as follows: Fe-89%, Cd-100%, Cu-30%, Cr-13%, Pb-82%, Ni-6%, Zn-66%, Mn-67%, Hg-62%, As-3%, Al-83% Ag-18%, V-6%, Se-0%.

Compared to other regions of the lake in 1980, southern Lake Huron had the highest concentrations of iron and aluminum. It had the lowest concentrations of copper, chromium, lead, zinc, and perhaps nickel.

17. KEY WORDS AND DOCUMENT ANALYSIS

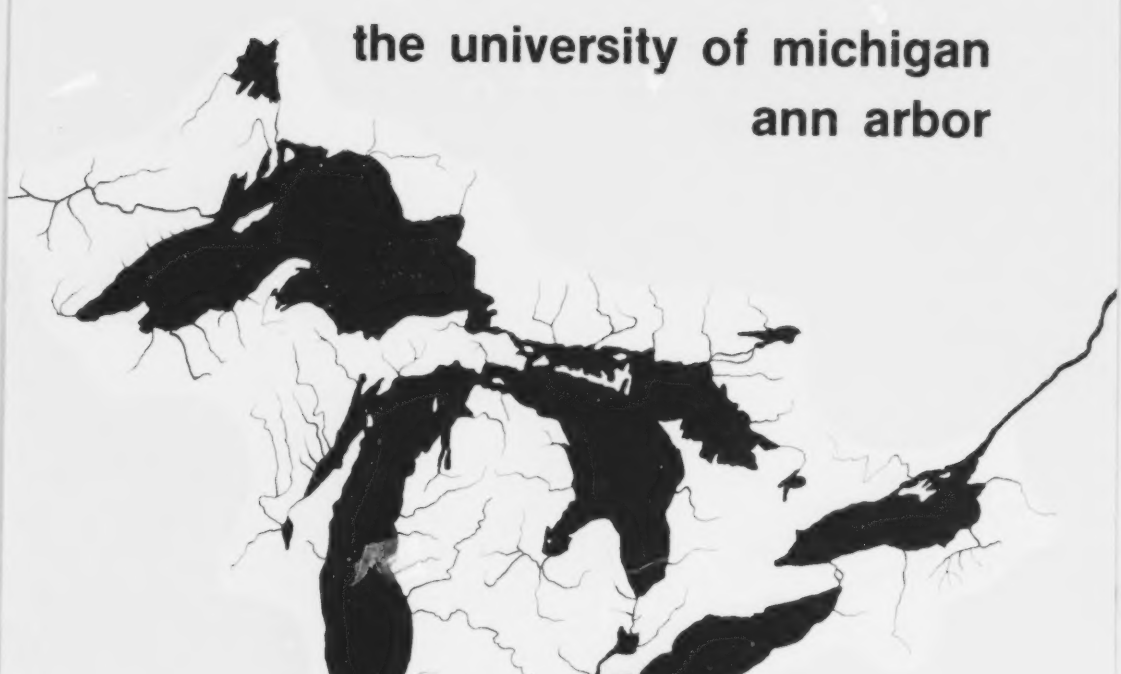
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Quality monitoring, trace metals, total, dissolved, particulate.	Lake Huron Toxic	

18. DISTRIBUTION STATEMENT Available through NTIS Springfield, VA 22161	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 50
	20. SECURITY CLASS (This page) Unclassified.	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

PB83-195719

the university of michigan
ann arbor



TRACE METAL CHEMISTRY OF THE WATERS OF LAKE HURON

Ronald Rossmann

GREAT LAKES RESEARCH DIVISION
Publication 21

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

GREAT LAKES RESEARCH DIVISION / Publication 21

TRACE METAL CHEMISTRY OF THE WATERS OF LAKE HURON

Ronald Rossmann

Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan 48109

Grant Nos. R005546010 and R005546011

Project Officer
David C. Rockwell

U.S. Environmental Protection Agency
Great Lakes National Program Office
Region V
Chicago, Illinois

1982

i.a

DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement numbers R005546010 and R005546011 to the University of Michigan, it has been subject to the Agency's peer and administrative review, and it has been approved for publication. The contents reflect the views and policies of the Agency. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	v
ABSTRACT	vi
INTRODUCTION	1
METHODS	2
Bottle Preparation	2
Filter Preparation	2
Vial Preparation	2
Filtration Equipment and Filtration	2
Sampling Equipment and Collection Technique	3
Sample Preparation	4
Water Samples	4
Particulate Samples	5
Sample Analysis	5
Data Reduction and Calculation of Concentrations	6
Concentration Calculation	6
Detection Limit	6
Sample Collection	6
RESULTS AND DISCUSSION	8
Limit of Detection	8
Lake Water	8
Particulate	8
Blanks	9
Lake Water	9
Particulate	9
Quality Assurance Samples	11
Metal Concentrations in Lake Huron Water	11
Iron	11
Cadmium	14
Copper	16
Chromium	18
Lead	20
Nickel	20
Zinc	22
Manganese	24
Mercury	26

Arsenic 26
Aluminum 28
Silver 30
Vanadium 30
Selenium 32

SUMMARY 40

LITERATURE CITED 41

ACKNOWLEDGMENTS

This study was supported by the Great Lakes National Program Office of the United States Environmental Protection Agency (grant numbers R005546010 and R005546011).

I wish to thank the crew of the R/V *Roger R. Simons* and the Great Lakes National Program Office, especially David Rockwell who made available the STORET historical trace metal data. Special thanks to Janice Pappas and Linda D. Damaske who participated in the analysis, to Stephen Schneider, Marion Luckhardt, and Beverly McClellan for preparation and production of the manuscript, to Timothy Henry, William L. Yocum, and Laurie Ponte for assistance with preparations for sample collection, and to April R. Rossmann for drafting the figures. Alfred M. Beeton, David Rockwell, Tom Tisue, Steven Eisenreich, Ken Lum, and Clifford P. Rice reviewed the manuscript and provided helpful suggestions.

ABSTRACT

To provide information on total and dissolved trace metals, Lake Huron waters were analyzed for iron, cadmium, copper, chromium, lead, nickel, zinc, manganese, mercury, arsenic, aluminum, silver, vanadium, and selenium concentrations. Median total, dissolved, and particulate concentrations in $\mu g/L$ for each metal are: 4.8, .80, and 6.4 for iron; .015, 0, and .012 for cadmium; .40, .28, and .12 for copper; .13, .11, and .017 for chromium; .022, .0087, and .041 for lead; .54, .49, and .034 for nickel; .29, .17, and .33 for zinc; .67, .28, and .58 for manganese; .011, .0042, and not measured for mercury; .21, .22, and .0086 for arsenic; 8.8, 3.1, and 15 for aluminum; .0090, .0058, and .0013 for silver; .22, .24, and .014 for vanadium; and .48, .48, and 0 for selenium, respectively.

For each metal, the total does not necessarily equal the dissolved plus particulate fractions. The differences are particularly accentuated for those metals having a large proportion of their total concentration resident in particulate matter. Differences appear to be an artifact of analytical technique. The percentage of metal in particulate matter for each element is as follows: Fe—89%, Cd—100%, Cu—30%, Cr—13%, Pb—82%, Ni—6%, Zn—66%, Mn—67%, Hg—62%, As—3%, Al—83%, Ag—18%, V—6%, and Se—0%.

Compared to other regions of the lake in 1980, southern Lake Huron had the highest concentrations of iron and aluminum. It had the lowest concentrations of copper, chromium, lead, zinc, and perhaps nickel. The North Channel had relatively elevated concentrations of copper, nickel, manganese, and vanadium. Georgian Bay had the highest selenium and lowest iron, arsenic, and aluminum concentrations.

INTRODUCTION

During 1980, total trace metal samples were collected from Lake Huron, Georgian Bay, and the North Channel by USEPA and CCIW for total metal analyses by USEPA CRL (Central Regional Laboratory). The dates of collection were April 13–23, May 5–17, May 5–June 27, and July 18–29.

Total trace metal concentrations do not only vary over time and space due to cultural loadings, but they also respond to increased particulate loadings which result from sediment resuspension and increased runoff. Those metals associated with resuspended lake bottom sediments, river transported particulates, runoff from the shoreline, atmospheric inputs, and wave-induced bluff erosion can vary by orders of magnitude over short periods of time. As synoptic cruises generally last for one or more weeks, it is difficult to compare one region of the lake to another, especially if an event occurs which increases the particulate matter concentration in the water column. To complement USEPA CRL total metal data, total and soluble metal samples were collected by the author.

Historical trace metal data are of two types, total concentration and filtered concentration. Within these data, a common operational distinction between dissolved and particulate is a particle diameter of 0.45 μm. Anything passing through a 0.45 μm pore size filter is considered soluble.

The bulk of historical data which exist for Lake Huron is contained in STORET, primarily Canada Centre for Inland Waters and State of Michigan data, and are reported, in part, in the International Joint Commission 1977 report "The Waters of Lake Huron and Lake Superior," Volume II, Parts A and B. In these volumes, tributary inputs are generally expressed as total metal concentrations. For the open lake, the data are a combination of total and filtered water concentrations. As total and filtered trace metal concentrations cannot be compared on any scientific basis, analysis of filtered as well as unfiltered water samples was necessary for the prediction of long-term trends by use of historical data and for comparison of nearshore to offshore samples.

To ensure that as many results as possible were reported as real numbers and not as limits of detection, it was imperative that the analyses be performed with the most sensitive techniques. The most sensitive technique for most metals of interest is flameless atomic absorption spectrophotometry using a graphite furnace.

METHODS

BOTTLE PREPARATION

Polyethylene bottles with polypropylene caps, which have been used since 1969 only for the storage of trace metal water samples, were emptied of their previous samples. Each was then filled with 5% (v/v) HNO_3 and allowed to soak for 24 hours. With the caps on, the outsides of the bottles were washed with soap and water, rinsed with hot tap water, and then rinsed with distilled water. The bottles were then opened, triple-rinsed with distilled water, and triple-rinsed with distilled-deionized water. Each bottle was then filled with distilled-deionized water and allowed to soak overnight. The following day the content of each bottle was analyzed for zinc, the most easily contaminating element. If any bottle had a zinc concentration appreciably above the concentration of zinc in fresh distilled-deionized water (50 ng/L), the bottle was rejected. Bottles which passed the zinc analysis test were emptied, and 5 mL of Ultrex® nitric acid were added to each. The tightly-capped bottles were then sealed in polyethylene bags.

FILTER PREPARATION

Millipore Fluoropore® filters (FEP teflon) were triple-rinsed with and then soaked in reagent grade ethyl alcohol (190 proof) for 12 to 24 hours in a polyethylene bottle. An organic wetting agent is necessary to render these filters functional for inorganic solutions. The ethyl alcohol was then analyzed for any zinc contamination. If zinc contamination was present, the filters were again rinsed and soaked until no zinc contamination was observed. They were then stored in reagent grade ethyl alcohol in the bottles in which they were cleaned. Two different pore-size filters (0.5 μm and 0.2 μm) were used.

VIAL PREPARATION

Polyethylene vials for storage of filters and their trapped particulates were prepared in a manner similar to that for the polyethylene bottles. The exception was that no analyses for zinc were made. The vials were also stored in sealed polyethylene bags.

FILTRATION EQUIPMENT AND FILTRATION

The filtration equipment used consisted of an approximately 9.5 cm diameter, 250 mL capacity polypropylene Buchner funnel. To increase the surface area of filtration,

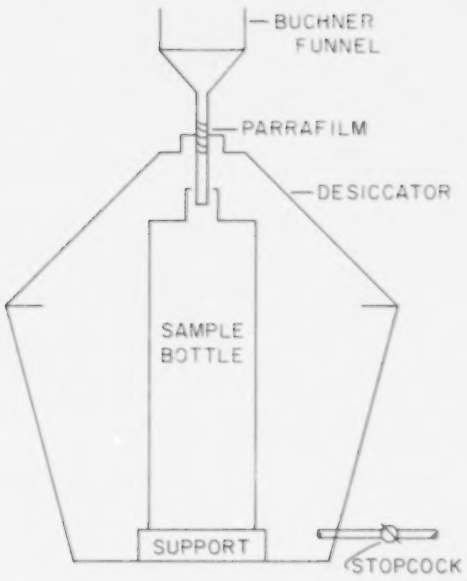


FIGURE 1. Filtration system used to filter trace metal water samples. The entire system is used within a laminar flow hood.

additional holes (enough to double the number) were drilled in the funnel. The filter funnel was cleaned in a manner similar to the polyethylene bottles. For vacuum filtration, the funnel was fitted with parafilm to form a seal with a hole drilled in the top of a Bel Art® (273 mm flange OD) polycarbonate-polypropylene vacuum desiccator (Figure 1). Samples were filtered through the Buchner funnel with its Teflon filter into the prepared sample bottles housed within the vacuum desiccator. Vacuum was obtained with an oilless vacuum pump, and all filtration occurred under a laminar flow hood. During filtration, 250 mL of distilled-deionized water were filtered and discarded, 1 L of distilled-deionized water was filtered and collected for use as a filtration blank, and finally 1 to 2 L of sample were filtered and collected.

SAMPLING EQUIPMENT AND COLLECTION TECHNIQUE

The sampling equipment consisted of a 2-L polyethylene bottle with polypropylene cap, polyethylene rope with an attached 4-L polypropylene bottle filled with sand for a weight, polyethylene tubing, and a Millipore® pressurized tank (Figure 2). The tank was pressurized to 5.2 bars (75 psi) with an oilless pump to minimize any air contamination of the sample bottles. The sampling bottle was prepared in the same way as all other bottles. The system used prevented contamination from any surface microlayer and allowed rinsing of the sampler at its sampling depth with lake water. All sampling was done on the leeward side of the ship to prevent sampling of water through which the ship had drifted. All samples were collected from a depth of 1 m.

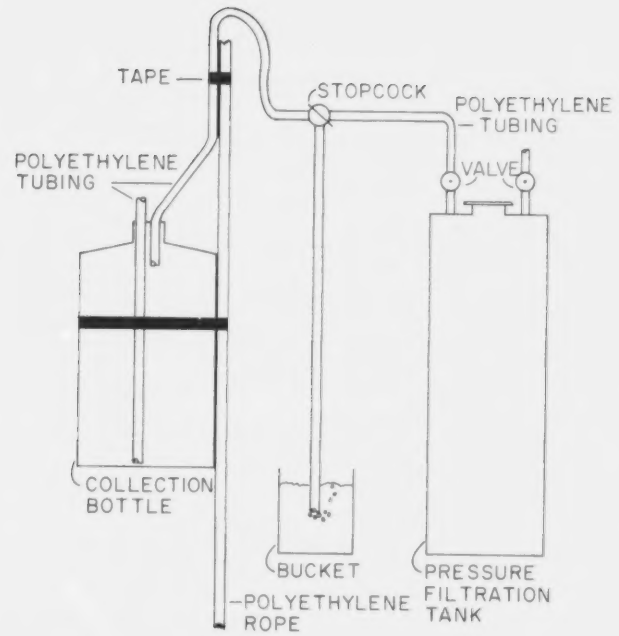


FIGURE 2. Sampling system used for collection of trace metal water samples.

The routine collection procedure used was as follows:

1. The collection bottle, filled with polyethylene-bucket-collected water from the previous station, was lowered to a depth of 1 m.
2. Using the pressure filtration tank, the bottle was pressurized to force out its contents.
3. Using the 3-way stopcock, the bottle was allowed to fill slowly to prevent its collapse. The rate of filling was observed by submerging a piece of tubing connected to the stopcock in a bucket of water (Figure 2).
4. Steps 2 and 3 were repeated two to three times.
5. Finally, the full collection bottle was brought to the surface.
6. The full collection bottle was removed, capped, and replaced with another collection bottle.

SAMPLE PREPARATION

Water Samples

The water samples required little preparation prior to analysis. Samples were pre-concentrated nine- to ten-fold by freeze drying before analysis for arsenic, selenium, lead, mercury, silver, and vanadium. Samples for freeze drying were transferred to pre-cleaned widemouth polyethylene bottles, frozen, and placed inside of freeze drier flasks. At no time were the flasks warmed to speed the process. Samples were seldom freeze dried to dryness. Those that did go to dryness had 50 μL of concentrated

TABLE 1. Sample loss during freeze drying.

Element	Prepared Concentration, μg L	Measured Concentration, μg L	Percent Loss
As	.1	.082	18
	.2	.17	15
Hg	.1	.1	0
Pb	.1	.10	0
	.2	.22	10[1]
	.1	.087	13
Se	.5	.74	30
	.2	.34	20
V	.5	.36	28

[1]Freeze-dried sample was contaminated by .02 giving a ten percent increase in concentration.

Ultrex® nitric acid added before being brought to final volume with distilled-deionized water. The polyethylene freeze drying bottles were then placed on their sides and rotated for 12 hours to ensure removal of any material adhering to the sides of the bottles. The samples were then stored in their freeze drying bottles until analysis. A study of the possible loss of each of these elements during freeze drying was done (Table 1). Although loss appears high in some cases, it may be in part accounted for by measurement inaccuracies while bringing the freeze-dried sample to volume. To avoid contamination, the polyethylene bottles in which samples were freeze dried were marked for initial and final volumes. Because of this method, a ten percent error in final sample volume was expected. In the future, the method of measuring volumes will be improved. As the loss numbers are unconfirmed at this time, no correction of the results was made. However, the data for the freeze-dried elements should be viewed as possibly being 10 to 30% low biased. Since completion of this work, we have discovered that mercury samples are intermittently contaminated during freeze-drying. This was discovered with the recent acquisition of more sensitive equipment which now permits us to analyze directly for mercury with no preconcentration.

Particulate Samples

The filters with their particulate matter remained frozen in their individual vials until the time for dissolution. The particulates were extracted inside Teflon bottles in 10% v/v Ultrex® nitric acid with several additions of Ultrex® 30% v/v hydrogen peroxide. Each sample was extracted in a hot water bath at 80°C for 40 hours. The caps were left loose on each bottle to prevent contamination and high evaporation. After extraction, the extract was transferred to pre-cleaned polyethylene bottles. All work, except the extraction, was done in a laminar flow hood.

SAMPLE ANALYSIS

All trace metal analyses were done by flameless atomic absorption spectrophotometry using a Perkin Elmer® Model 5000 atomic absorption spectrophotometer equipped with a Perkin Elmer® Model 500 graphite furnace and Model AS-1 automatic sampler. The atomic absorption spectrophotometer was aways run with background correction and in peak area mode. Coated graphite tubes were always

used in the graphite furnace. The furnace was programmed for drying at 110 to 120° C with a ramp time of 5 seconds. The drying time varied depending upon the sample sizes injected into the furnace (10 to 100 μL). Generally, ashing was at 50°C less than recommended by the manufacturer (Perkin Elmer 1977) and had a duration of 10 seconds with a 1 second ramp time. Atomization was at the temperature recommended by the manufacturer (Perkin Elmer 1977). A 1 second ramp time was used with an additional hold time of 5 seconds. The peak area integration occurred for all 6 seconds. Mercury analyses were done by the cold-vapor technique (USEPA 1979) using the Perkin Elmer® Model 5000. All sample handling was done in a laminar flow hood, and all analyses were done at the Great Lakes Research Division, The University of Michigan.

DATA REDUCTION AND CALCULATION OF CONCENTRATIONS

Concentration Calculation

During each run of samples, a minimum of four standards, two water blanks, and two blank injections were analyzed. A regression line was fit through the standards and water blanks. If the y-intercept was above the reading obtained for the blank injections, the mean reading of the blank injections was used as the y-intercept. Any obviously anomalous readings for standards or blanks were discarded prior to calculating the regression line. The elemental concentrations in the samples were then calculated using the equation of the regression line. Most samples were run in triplicate. This allowed anomalous readings to be discarded. A standard deviation was calculated for each sample. Because of the low concentrations found in Lake Huron waters, the method of standard additions was judged to be unsuitable. Minor contamination of samples during the additions resulted in large errors. Previous work at higher concentrations yielded good agreement between results obtained by standard addition and those obtained using standard curves.

Detection Limit

Detection limits were calculated for each run of samples. The limit was calculated from the standard deviation of multiple injections of a blank. The blank was either nothing or distilled-deionized water atomized in the graphite furnace. The standard deviations for a run were averaged and multiplied by 1.96 for calculating limit of detection at 95% confidence (Hoel 1967). The result was divided by the slope of the regression line for the standards. This converted the number to a concentration. In general, the limits of detection for total and soluble samples were the same. Because of the way detection limit was calculated, it was desirable to have a detection limit lower than bottle or filtration blanks.

The median concentrations presented for historical data were estimated by the computer construction of histograms of occurrence.

SAMPLE COLLECTION

During late July and early August 1980, trace metal samples were collected from Lake Huron, Georgian Bay, and the North Channel using the R/V *Roger R. Simons.*

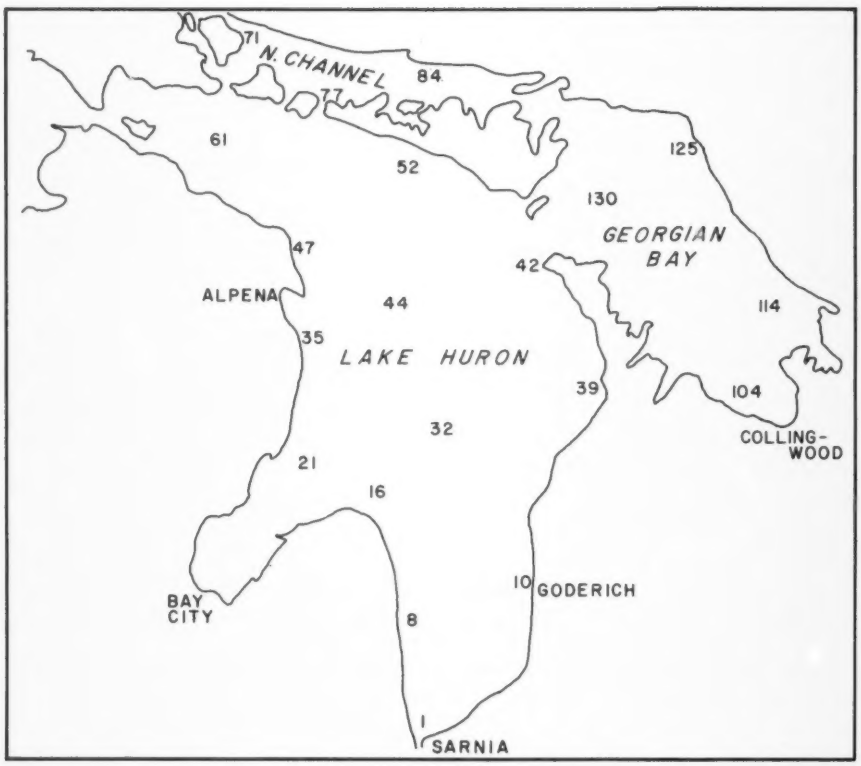


FIGURE 3. Sampling stations for trace metals in water in 1980.

The stations were chosen to give as wide a representation of the open lake as possible (Figure 3). Twenty stations were occupied, and three of these were sampled in replicate. At each station, a total sample, a 0.5 μm pore-size filtered sample, a bottle plus acid blank, and a bottle plus acid plus filtration blank were collected. At six of the stations, an additional 0.2 μm pore-size filtered sample and its associated blank were collected.

RESULTS AND DISCUSSION

LIMIT OF DETECTION

Lake Water

The limit of detection for each run was determined by calculating the standard deviation of readings for multiple atomizations of nothing or distilled-deionized water. The standard deviations were then averaged, multiplied by 1.96 to provide for the 95% level of confidence (Hoel 1967), and divided by the slope of the regression line for the standards to convert to a concentration. At the 95% level of confidence, the average limit of detection for each element is listed in Table 2.

Particulate

In a manner similar to that for lake water, the mean limits of detection were calculated (Table 2). These were all calculated on the basis of the particulates in 2 L of water being dissolved in 50 mL of solvent.

For both the lake water and particulate analyses, the limits are mean limits and do not necessarily represent the ultimate detection limits. In general, the analyses were

TABLE 2. Mean limit of detection

Element	Particulate[1] Limit, μg L	Total and Dissolved Limit, μg L
Ag	.00036	.0040[2]
Al	.014	.12
As	.010	.035[2]
Cd	.00096	.0030
Cr	.00071	.0071
Cu	.033	.013
Fe	.30	.13
Hg	—	.020[3]
Mn	.035	.021
Ni	.0090	.081
Pb	.0031	.0050[2]
Se	.013	.053[2]
V	.0063	.028[2]
Zn	.011	.10

[1]These limits represent 2 L of filtered particulate extracted into 50 mL of solvent. For some samples, only 1 L of filtered particulate was extracted. Hence, limits should be doubled.
[2]Concentrated 10-fold by freeze drying.
[3]Concentrated 9-fold by freeze drying.

done under conditions which allowed for a detection limit lower than the concentrations measured in the samples. This limited the quantity of data points below the limit of detection. In cases where the sample results were below the best obtainable limit of detection, they are so designated.

A second set of detection limits was applied to all results. These limits were based upon the standard deviation of the total and filtered field blanks. The standard deviation was calculated for each set of blanks, after obviously contaminated blanks were discarded, and doubled. This yielded the second limit of detection for the 95% level of confidence (Table 3). Again, sample results below the limit of detection are so indicated.

BLANKS

Lake Water

For every element analyzed, two blanks were obtained. These were the bottle plus acid blank and the bottle plus acid plus filtration blank. If these blanks were appreciably large, the water utilized to prepare the blanks was also analyzed. This was not possible for mercury. These data were then used to correct the sample results. The blanks for each element, corrected for the concentration within the preparation water, are listed in Table 4.

Particulate

During the extraction of particulates from the Teflon filters, two blanks were extracted. The first blank consisted of only the reagents being added to the Teflon extraction bottles. The second blank consisted of a Teflon filter handled in the same way as those in the field. Instead of sample, distilled-deionized water was passed through these filters. These filters were then extracted in the same way as those containing the particulate samples. A summary of the blank corrections is found in Table 4. Whenever the lake water or particulate blanks were above the limit of detection, the sample results were blank corrected.

TABLE 3. Limit of detection based upon standard deviation of blanks (μg/L).

Element	Total	Filtered	Particulates
Fe	.12	.15	.025
Cd	.0055	.017	.00083
Cu	.058	.058	.012
Cr	.019	.035	.0022
Pb	.034	.023	.012
Ni	.013	.022	.0048
Zn	.14	.22	.14
Mn	.017	.021	.011
Hg	.089	.20	—
As	.014	.020	.0014
Al	.34	.49	.11
Ag	.00099	.0026	.000035
V	.039	.041	.0015
Se	.011	.012	.0078

TABLE 4. Blank corrections applied to total, dissolved sample, and particulate results (μg/L).

Element	Correction for Total Samples	Correction for Filtered Samples	Filter Particulate Correction	Reagents Plus Glassware Particulate Correction	Total Particulate Correction
Ag[1]	.0010[2]	.0017[2]	.000090[2]	.000029[2]	.000029[2]
Al	.49	.58	.050	.50	.55
As[1]	.0080[2]	.014[2]	.00020[2]	.0027[2]	.0029[2]
Cd	.0096	.021	.0064	.00088	.0072
Cr	.015	.028	.0015	.0057	.0072
Cu	.0083	.012	.0087	.0083[2]	.017
Fe	.27	.29	.020	.039	.059
Hg	.045	.10	—	—	—
Mn[1]	.014[2]	.017[2]	.016[2]	.0043[2]	.020[2]
Ni[1]	.011[2]	.016[2]	.0063	.0067	.013
Pb	.023	.024	.0075	.0051[2]	.0013
Se[1]	.0064[2]	.0069[2]	.00040[2]	.0045[2]	.0049[2]
V[1]	.018[2]	.025[2]	0.0[2]	.00065[2]	.00065[2]
Zn	.025	.084	.021	.065	.086

[1]No blank corrections made.
[2]Blank correction is uncertain due to being below the limit of detection.

QUALITY ASSURANCE SAMPLES

To provide for quality assurance, United States Environmental Protection Agency low level trace metal quality assurance samples were analyzed. Results are found in Table 5. In general, the measured and true concentrations are in good agreement. The most noteworthy differences are for zinc sample number 2, aluminum sample number 1, and copper sample number 4.

METAL CONCENTRATIONS IN LAKE HURON WATER

The historical trace metal data for Lake Huron include the years 1965, 1968, 1970, 1971, 1974, 1975, and 1976. These are open-lake data. The data for all years excluding 1968 and 1975 are contained in STORET. All historical data must be viewed with caution. At the time of their generation, they may or may not have represented the best information available for the state of the art. Instrumentation and methodology have improved considerably in the last 10 years, especially the last 5 years.

In the sections which follow, each element's 1980 concentration is discussed in terms of historical concentrations, regional variations, and partitioning between the "dissolved" and particulate fractions. The results for each element are presented as individual station concentrations, median concentration, and mean concentration. All discussions of areal distribution for dissolved and particulate concentrations are based solely upon the .5μm filtered samples.

Iron

Total iron concentrations in 1980 for Lake Huron ranged between 1.4 and 25 μg/L (Table 6). The median concentration in Georgian Bay (GB) of 3.1 μg/L was similar to the 2.9 μg/L for northern and central Lake Huron but less than the 5.3 μg/L for the North Channel (NC). Station 71, receiving water from Lake Superior, had an iron concentration of 25 μg/L; and Station 10, which receives river inputs, had an iron concentration of 22 μg/L. The stations in southern Lake Huron (SLH) exhibited substantially elevated median iron concentrations (14 μg/L).

Total iron data exist for the years 1965, 1968, 1970, 1974, and 1975. For the years 1970 and 1974, obviously high results were discarded. Excluding 1965, the historical data are consistent and have median concentrations ranging from 2 to 21 μg/L (Table 7). The data for 1980 have a median concentration of 4.8 μg/L and are most similar to those of 1974. Because of the large differences between the 1980 and historical medians, historical iron data should be used with caution.

Dissolved 1980 iron concentrations ranged between 0.0 and 11 μg/L (Table 6). The median concentration for Georgian Bay was .10 μg/L and for the North Channel was .38 μg/L. These are considerably lower than that for the open lake (excluding the southern end) which was .80 μg/L. Again, station 71 had an elevated concentration. Southern Lake Huron had an elevated median iron concentration of 2.7 μg/L. Station 21 in outer Saginaw Bay also had an elevated dissolved iron concentration. There was no apparent difference between concentrations obtained for .5 μm filtered water and those obtained for 0.2 μm filtered water.

Dissolved iron data exist for the years 1970, 1971, 1974, and 1976. The median concentrations range from .5 to 3 μg/L (Table 7). The data for all years except 1971

TABLE 5. Results of analyses of quality assurance samples (μg/L).

Element	Sample Number	True Concentration with Acceptance Limits	Measured Concentration
Fe	1	20 ± 2	23.
	2	25 ± 2	23.
	3	4 ± .4	4.3
	4	5 ± .4	4.4
Mn	1	8 ± 2	7.7
	2	13 ± 2	13.
	3	1.6 ± .4	1.4
	4	2.6 ± .4	2.3
Ni	1	4 ± 2	3.6
	2	8 ± 2	6.3
	3	.9 ± .4	.86
	4	1.6 ± .4	1.7
Se	1	2 ± 1	2.4
	2	5 ± 1	5.8
	3	.4 ± .2	.42
	4	.7 ± .2	.70
Zn	1	17 ± 3	15.
	2	28 ± 3	21.
	3	3.2 ± .6	3.2
	4	5.3 ± .6	5.2
Al	1	40 ± 5	38.
	2	50 ± 5	48.
	3	8 ± 1	9.7
	4	10 ± 1	14.
As	1	12 ± 3	14.
	2	30 ± 3	33
	3	2.4 ± .6	2.2
	4	6 ± .6	5.5
Cd	1	2 ± 1	3.9
	2	5 ± 1	4.2
	3	.4 ± .2	.31
	4	1 ± .2	.74
Cr	1	3 ± 2	2.8
	2	7 ± 2	6.7
	3	.5 ± .4	.44
	4	1.4 ± .4	1.2
Cu	1	5 ± 2	4.9
	2	9 ± 2	8.6
	3	1 ± .4	1.2
	4	1.8 ± .4	3.0
Pb	1	4 ± 2	3.5
	2	9 ± 2	9.7
	3	.8 ± .4	1.0
	4	1.8 ± .4	1.9

TABLE 6. Iron concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	9.3 (.45)	2.7 (.14)	—	6.5 (.071)	—
1SLH	15. (.25)	4.0 (.075)	—	18. (.50)	—
8SLH	11. (.40)	1.9 (.061)	3.3 (.20)	23. (.50)	14. (.14)
10SLH	22. (.65)	11. (.058)	—	15. (.38)	—
16	2.4 (.31)	.059 (.012)[1]	.72 (.14)	2.8 (.20)	3.9 (.14)
21	4.7 (.15)	5.1 (.060)	—	6.4 (.021)	—
32	3.4 (.11)	.80 (.060)	.66 (.044)	12. (.058)	2.7 (.014)
35	4.8 (.32)	.15 (.080)[1]	—	6.5 (.0071)	—
39	2.7 (.023)	.20 (.084)	—	4.0 (.014)	—
42	2.9 (.25)	.96 (.24)	.79 (.096)	3.6 (.035)	6.5 (.17)
44	1.8 (.021)	1.1 (.22)	—	4.4 (.044)	—
44	2.2 (.21)	.96 (.0058)	—	21. (3.3)	—
47	7.3 (.27)	0.0 (.085)[1]	—	3.9 (.64)	—
52	2.1 (.060)	.76 (.097)	—	5.6 (.099)	—
61	6.9 (.15)	2.2 (.31)	—	4.7 (.099)	—
61	7.2 (.18)	1.7 (.028)	—	15. (.28)	—
71NC	25. (.21)	4.7 (.40)	—	8.9 (.035)	—
77NC	5.3 (.11)	.12 (.047)[1]	—	7.4 (.036)	—
84NC	5.0 (.22)	.38 (.12)	1.6 (.17)	5.3 (.035)	8.1 (.14)
104GB	5.0 (.12)	.10 (.034)[1]	—	11. (.42)	—
114GB	3.1 (.13)	.20 (.028)	—	2.2 (.057)	—
125GB	3.2 (.14)	.11 (.054)[1]	—	5.1 (.19)	—
130GB	1.4 (.070)	.070 (.033)[1]	.25 (.064)	2.1 (.021)	4.2 (.16)
$\bar{x}$ =	6.7	1.7	1.2	8.4	6.6
σ =	6.2	2.5	1.1	6.1	4.1
n =	23	23	6	23	6
median =	4.8	.80	.72	6.4	4.2

[1]Below limit of detection.

TABLE 7. Comparison of 1980 to historical Lake Huron water iron concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965	288.	265.	215	100.				
1968[1]			37 39	22.				
1970	21.	25.	12	12. 15.	6.3	8.4	23	1.
1971					3.2	2.7	182	2. 3.
1974[2]	21.	16.	94	2. 19.	2.7	2.6	119	1. 2.
1975[3]	18.	5.	10					
1976					2.0	1.9	18	.5
1980	6.7	6.2	23	4.8	1.7	2.5	23	.80

[1]Weiler and Chawla (1969).
[2]Concentrations above 50μg L excluded.
[3]Nearshore waters; Polkoski *et al.* (1978).

may be at or near the limit of detection. If this is true, these data are not useful for predicting trends. The data for 1971 are suspect. The 1980 data median concentration is .80 μg/L. It is comparable to all historical medians except that of 1971.

In 1980, particulate iron concentrations ranged from 2.1 to 23 μg/L (Table 6). The dissolved plus particulate metal concentration does not necessarily equal the total result. This is particularly true for iron, cadmium, lead, and aluminum and perhaps zinc, manganese, and mercury, and any other metal for which the particulate fraction is the major contributor to the total. In most cases, the total metal concentration is lower than the sum of the particulate and dissolved fractions. Recent work has shown that the total metal concentration was not measured. Either the small volume (100 μL or less) sampled for injection into the graphite furnace was not a representative subsample of the suspended particulate matter or the particulate matter was not properly atomized within the furnace. The replicate samples from station 1 were analyzed nearly 2 years after collection for aluminum. The aluminum concentration increased over the previously measured concentration. The new concentration equals the sum of the dissolved plus particulate fractions. In addition, each was boiled with additional nitric acid. The concentration did not increase. The storage time of nearly 2 years apparently was long enough to allow for the extraction of the particulate matter by the nitric acid (5 mL of concentrated HNO_3 to 1 L of sample) used to preserve the samples. Median concentrations were lowest in Georgian Bay (2.2 μg/L) and highest in southern Lake Huron (15 μg/L). Excluding southern Lake Huron, the North Channel, and Georgian Bay, the open lake median concentration was 4.7 μg/L. The median concentration in the North Channel was 7.4 μg/L. On the average, 89% of the total iron was associated with the particulate matter (> .5 μm in diameter).

Cadmium

Total 1980 cadmium concentrations ranged from .0017 to .061 μg/L (Table 8). Southern Lake Huron (SLH) had the highest median concentration (.019 μg/L), followed by the North channel (NC) with .015 μg/L, the remainder of the open lake (.011 μg/L), and finally Georgian Bay (GB) with .0058 μg/L.

Historical information for total cadmium is available for 1974 and 1976. The 1974 data have a median concentration of 0.2 μg/L, and the 1976 data have a median concentration of .020 μg/L (Table 9). The 1974 data are at or near the limit of detection. The 1980 median concentration is .015 μg/L. The order or more of

TABLE 8. Cadmium concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.019 (.0062)	.0012 (.0060)[1]	—	.0066 (.0010)	—
1SLH	.0087 (.0040)	.0033 (.0016)[1]	—	0.0 (.00078)[1]	—
8SLH	.039 (.014)	.017 (.00085)	.0010 (.012)[1]	.15 (.0015)	0.0 (.00048)[1]
10SLH	.033 (.0050)	.046 (.0025)	—	.0016 (.00068)	—
16	.016 (.0090)	0.0 (.0020)[1]	.027 (.0032)	.0034 (.00057)	.0042 (.00028)
21	.0097 (.0036)	0.0 (.00069)[1]	—	.048 (.00035)	—
32	.015 (.0038)	0.0 (.0)[1]	0.0 (.0044)[1]	.019 (.0)	0.0 (.0056)
35	.016 (.0017)	0.0 (.0018)[1]	—	.038 (.0020)	—
39	.0087 (.00064)	0.0 (.0045)[1]	—	.00082 (.00080)[1]	—
42	.0017 (.0029)[1]	0.0 (.0017)[1]	0.0 (.0017)[1]	.0068 (.00090)	0.0 (.00018)[1]
44	.011 (.0025)	0.0 (.0)[1]	—	.013 (.00020)	—
44	.0087 (.00028)	0.0 (.0035)[1]	—	.011 (.00059)	—
47	.025 (.0034)	.0039 (.0018)[1]	—	.037 (.00083)	—
52	.014 (.0011)	.0024 (.0021)[1]	—	.022 (.00010)	—
61	.061 (.0084)	.0051 (.0025)[1]	—	.012 (.00067)	—
61	.0055 (.0041)[1]	0.0 (.0012)[1]	—	.0053 (.00021)	—
71NC	.015 (.0032)	0.0 (.00083)[1]	—	.020 (.00057)	—
77NC	.015 (.0024)	0.0 (.0033)[1]	—	.0070 (.00055)	—
84NC	.016 (.0014)	0.0015 (.00092)[1]	0.0 (.0026)[1]	0.0 (.0039)[1]	.0034 (.00014)
104GB	.0047 (.0028)[1]	0.0 (.0016)[1]	—	.026 (.0067)	—
114GB	.017 (.0022)	.0071 (.0037)[1]	—	.0025 (.00078)	—
125GB	.0058 (.0050)	.00030 (.00085)[1]	—	.041 (.00021)	—
130GB	.0076 (.0060)	0.0 (.0025)[1]	0.0 (.0059)[1]	.014 (.00028)	0.0 (.00064)[1]
$\bar{x}$ =	.016	.0038	.0047	.021	.0013
σ =	.013	.010	.011	.031	.0020
n =	23	23	6	23	6
median =	.015	0.0	0.0	.012	0.0

[1]Below limit of detection.

TABLE 9. Comparison of 1980 to historical Lake Huron water cadmium concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std.	N	Median
1965					< 5.	0.0	37	< 5.
1970					1.0	0.0	2	1.
1971					.71	.51	111	1.
1974	.30	.16	42	.2	2.2	.22	70	.2
1976	.034	.038	38	.020	.057	.064	34	.030
1980	.016	.013	23	.015	.0038	.010	23	0.0

magnitude higher median for the 1974 data leads to the conclusion that these data, which are at their limit of detection, are of limited usefulness in predicting trends. The 1980 and 1976 median concentrations are very similar.

The 1980 dissolved cadmium concentrations ranged from 0.0 to .046 μg/L (Table 8). The median concentration of cadmium in southern Lake Huron (.0033 μg/L) was considerably higher than that for the remainder of the lake (0.0 μg/L). No significant difference in concentrations between .5 μm and .2 μm filtered samples was evident because most of the results were below the limit of detection.

Dissolved cadmium data are available for 1965, 1970, 1971, 1974, and 1976. Excluding 1965, the median concentrations range from 0.03 to 1 μg/L (Table 9). Excluding 1976, 1977, and 1978, the historical data for each of the years appear to be at or near the limit of detection. The 1980 median concentration is 0.0 μg/L. The difference between this median and those of the historical data is large enough to warrant the discarding all but the 1976 historical data, which are at the limit of detection, for use in predicting trends.

Particulate cadmium concentrations ranged from 0.0 to .15μg/L (Table 8). Southern Lake Huron median concentration (.0016 μg/L) was lower than those for the remainder of the lake (.012 μg/L), Georgian Bay (.014 μg/L), and the North Channel (.0070 μg/L). An average of 100% of the total cadmium concentration resided in the particulate matter.

Copper

Total copper concentrations ranged from .22 to .64 μg/L (Table 10). Median concentrations were .38 μg/L for the northern and central Lake Huron, .23 μg/L for southern Lake Huron (SLH), .47 μg/L for Georgian Bay (GB), and .62 μg/L for the North Channel (NC). Station 61 results illustrate an obvious sample contamination from the ship at the time of sampling. At the time of sampling, the scientific waste water holding tank was inadvertently emptied.

Total copper data exist for 1968, 1970, 1974, 1975, 1977, and 1978, and the median concentrations range from 1 to 4 μg/L (Table 11). The median of 1.0 for 1974 represents a result obtained by discarding results which were obviously in error. The 1980 median concentration (.40 μg/L) leads to the conclusion that all but the 1974, 1975, 1977, and 1978 data should be discarded. The usefulness of the 1974 and 1975 data is suspect. Some of the 1977 and 1978 data are at or near the limit of detection.

The 1980 dissolved copper concentrations ranged from .063 to .62 μg/L (Table 10). The median concentrations were .50 μg/L for the North Channel, .30 μg/L for Georgian Bay, .094 μg/L for southern Lake Huron, and .38 μg/L for the remainder of the lake. No significant difference was found between the .5 μm and .2 μm filtered samples.

TABLE 10. Copper concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.23 (.019)	.094 (.0042)	—	.014 (.0013)	—
1SLH	.22 (.010)	.063 (.0)	—	.038 (.0013)	—
8SLH	.48 (.034)	.026 (.015)	.42 (.032)	.048 (.0015)	.098 (.0)
10SLH	.23 (.015)	.20 (.0089)	—	.066 (.0013)	—
16	.36 (.0071)	.25 (.020)	.30 (.027)	.082 (.0077)	.13 (.0046)
21	.38 (.053)	.26 (.0046)	—	.39 (.020)	—
32	.34 (.050)	.28 (.025)	.21 (.0061)	.26 (.0046)	.035 (.0034)
35	.31 (.030)	.22 (.0046)	—	.66 (.0078)	—
39	.22 (.014)	.18 (.017)	—	.99 (.083)	—
42	.54 (.059)	.44 (.041)	.49 (.080)	.21 (.026)	.55 (.0084)
44	.50 (.025)	.30 (.047)	—	.067 (.00028)	—
44	.42 (.014)	.34 (.026)	—	.067 (.0075)	—
47	.38 (.050)	.26 (.0097)	—	.43 (.011)	—
52	.40 (.0047)	.38 (.0028)	—	19.7 (.15)[1]	—
61	1.7 (.0071)[1]	.48 (.0035)[1]	—	1.3 (.048)[1]	—
61	1.6 (.030)[1]	.34 (.015)[1]	—	.88 (.0035)[1]	—
71NC	.55 (.028)	.57 (.029)	—	.58 (.0028)	—
77NC	.61 (.011)	.37 (.021)	—	.16 (.0042)	—
84NC	.64 (.034)	.50 (.017)	.62 (.0023)	.12 (.0)	.79 (.0084)
104GB	.32 (.017)	.22 (.016)	—	.12 (.0)	—
114GB	.47 (.0057)	.30 (.046)	—	.074 (.0072)	—
125GB	.56 (.0050)	.43 (.0071)	—	.22 (.0078)	—
130GB	.57 (.027)	.35 (.00071)	.36 (.013)	.12 (.0071)	.043 (.0056)
$\bar{x}$ =	.42	.30	.40	.24	.27
σ =	.13	.12	.14	.26	.32
n =	21	21	6	20	6
median =	.40	.28	.36	.12	.098

[1]Result ignored for calculation of mean.

TABLE 11. Comparison of 1980 to historical Lake Huron water copper concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965					< 5.	0.0	37	< 5.
1968[1]			37-39	3.			37-39	3.
1970	4.8	1.9	12	4.	3.5	3.2	23	1.
1971					3.7	2.5	187	1.
1974	2.4	2.3	96	1.	2.1	1.7	200	1.0
1975[2]	1.6	0.8	10					
1976					.78	.26	18	.5-1.
1977	1.8	1.3	44	1.0	2.8	1.8	39	3.0
1978	.75	.30	23	1.0	.72	.30	23	1.0
1980	.42	.13	21	.40	.30	.12	21	.28

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.
[2]Nearshore waters; Poldoski *et al.* (1978).

Dissolved copper data are available for 1965, 1968, 1970, 1971, 1974, 1976, 1977, and 1978. Excluding 1965, median concentrations range from 0.5 to 1 μg/L (Table 11). Obviously contaminated sample results were discarded. The data of 1971, 1974, 1977, and 1978 are of limited usefulness because some of the concentrations were at or near the limit of detection. The 1980 median concentration is .28 μg/L. This is similar to the lowest values obtained during 1971 and 1974.

In 1980, particulate copper concentrations ranged from .014 to .99 μg/L (Table 10). Median concentration was lowest in southern Lake Huron (.038 μg/L). The lake had the highest median concentration (.26 μg/L). The North Channel and Georgian Bay were quite similar, with median concentrations of .16 and .12 μg/L, respectively. Thirty percent of the total copper was within the > .5 μm particulate fraction.

Chromium

Total chromium concentrations for 1980 ranged from .032 to .19 μg/L (Table 12). There was no apparent variation of concentration between various regions of the lake.

Total chromium concentrations are available for 1968, 1970, and 1974. Their median concentrations range from 1 to 3 μg/L (Table 13). The 1970 and 1974 data are at or near the limit of detection. The 1980 median concentration is .13 μg/L. This suggests that the 1968 and 1970 data should be discarded. The 1974 data are suspect.

Dissolved chromium concentrations for 1980 ranged from .0044 to .51 μg/L (Table 12). Like total chromium concentrations, there was no large regional variation. In general, the .2 μm filtered water concentration was less than the .5 μm filtered water concentration. Thus choice of filter pore size may be significant in its effect on final results.

Dissolved chromium data are available for 1965, 1968, 1970, 1971, and 1974. Excluding 1965 and 1968, the median concentrations vary from 0.1 to 1 μg/L (Table 13). The 1965, 1968, and 1970 data are much too high and should be discarded. The data for 1971 and 1974 are of limited usefulness because they are at or near the limit of detection. The data of 1971 and 1974 compare favorably with the 1980 median concentration of .11 μg/L.

Particulate 1980 chromium concentrations ranged from .0058 to .068 μg/L (Table 12). The southern Lake Huron median concentration (.0079 μg/L) was considerably less than those for the lake (.020 μg/L), the North Channel (.023 μg/L), and

TABLE 12. Chromium concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.15 (.023)	.12 (.0035)	—	.012 (.00014)	—
1SLH	.17 (.0042)	.070 (.025)	—	.0079 (.00047)	—
8SLH	.087 (.016)	.0044 (.0016)[1]	.17 (.019)	.013 (.00014)	.035 (.00028)
10SLH	.16 (.0)	.16 (.032)	—	.0061 (.00014)	—
16	.15 (.025)	.12 (.020)	.51 (.010)	.0058 (.000071)	.014 (.00042)
21	.17 (.018)	.38 (.032)	—	.027 (.00035)	—
32	.056 (.0013)	.20 (.043)	.034 (.0041)[1]	.014 (.000071)	.013 (.0014)
35	.19 (.011)	.15 (.010)	—	.068 (.00021)	—
39	.17 (.011)	.14 (.0050)	—	.013 (.00076)	—
42	.13 (.0042)	.14 (.026)	.079 (.0099)	.030 (.00026)	.014 (.0015)
44	.032 (.0013)	.022 (.0016)[1]	—	.022 (.00060)	—
44	.047 (.0013)	.12 (.011)	—	.027 (.00028)	—
47	.089 (.0042)	.045 (.0044)	—	.020 (.0015)	—
52	.091 (.0061)	.085 (.0064)	—	.013 (.0)	—
61	.12 (.0036)	.056 (.013)	—	.023 (.00080)	—
61	.14 (.013)	.063 (.0079)	—	.013 (.0015)	—
71NC	.13 (.016)	.12 (.0049)	—	.041 (.00035)	—
77NC	.066 (.0038)	.069 (.0025)	—	.023 (.00023)	—
84NC	.11 (.0014)	.10 (.0014)	.057 (.0050)	.018 (.00028)	.0082 (.00042)
104GB	.13 (.0046)	.11 (.0040)	—	.017 (.00038)	—
114GB	.12 (.00071)	.16 (.0085)	—	.012 (.00015)	—
125GB	.082 (.023)	.092 (.0064)	—	.045 (.00014)	—
130GB	.14 (.0057)	.024 (.0052)	.032 (.0038)[1]	.015 (.0011)	.019 (.00070)
$\bar{x}$ =	.12	.11	.15	.021	.017
σ =	.044	.078	.18	.014	.0094
n =	23	23	6	23	6
median =	.13	.11	.057	.017	.014

[1]Below limit of detection.

TABLE 13. Comparison of 1980 to historical Lake Huron water chromium concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965					< 5.	0.0	37	< 5.
1968[1]			37 39	1.6			37 39	1.6
1970	3.		1	3.	1.		1	1.
1971					.72	1.6	105	.1 .4
1974	1.3	.64	31	1.	.30	.24	128	.2
1980	.12	.044	23	.13	.11	.028	23	.11

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.

Georgian Bay (.015 μg/L). Only 13% of the total chromium resided in the >.5 μm particulate fraction.

Lead

The 1980 total lead concentrations ranged from 0.0 to .11 μg/L (Table 14). The median concentration in Georgian Bay (GB) of .028 μg/L was higher than the 0.0 μg/L in southern Lake Huron (SLH) and was somewhat higher than that for northern and central Lake Huron (.020 μg/L) and the 0.022 μg/L for the North Channel (NC). Sixty-one percent of the stations had undetectable concentrations.

Total lead data are available for 1968, 1970, 1974, 1975, 1977, and 1978. Median concentrations for these years range between 0.1 and 7 μg/L (Table 15). The 1977 and 1978 data are at or near the limit of detection. The 1980 median concentration is .038 μg/L. Because of the large difference, all historical data should be discarded or used with caution.

For 1980, dissolved lead concentrations ranged from 0.0 to .081 μg/L (Table 14). Sixty-five percent of the stations had undetectable lead concentrations and 33% of the stations had suspiciously high concentrations.

Dissolved lead information exists for the years 1965, 1968, 1970, 1971, 1974, 1976, 1977, and 1978. The 1977 and 1978 data are at or near the limit of detection. Excluding 1965, median concentrations range from 0.1–2 μg/L (Table 15). The 1980 median of .0089 μg/L warrants the discarding of all historical data.

Particulate lead concentrations for 1980 ranged from .0050 to .14 μg/L (Table 14). A large proportion of the stations (52%) have suspiciously high concentrations. This may have been due to sampling heterogeneity. The median concentration was lowest in southern Lake Huron (.018 μg/L), and it was somewhat lower in Georgian Bay (.031 μg/L) than in the lake (.042 μg/L) or in the North Channel (.042 μg/L). An estimated 82% of the total lead was associated with >.5 μm diameter particulate matter.

Nickel

In 1980, total nickel concentrations ranged between .31 and 3.8 μg/L (Table 16). Median concentrations for Georgian Bay (GB) (1 μg/L) and the North Channel (NC) (2.1 μg/L) were considerably higher than those for northern and central Lake Huron (.54 μg/L) or southern Lake Huron (SLH) (.33 μg/L). The concentration at station 71 in the North Channel was relatively low (.96 μg/L) compared to that of the

TABLE 14. Lead concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.021 (.0022)[1]	.031 (.0012)	—	.018 (.0)	—
1SLH	.010 (.0043)[1]	0.0 (.0)[1]	—	.040 (.0036)	—
8SLH	0.0 (.0024)[1]	.023 (.0039)[1]	0.0 (.00092)[1]	.051 (.0051)	.038 (.0025)
10SLH	0.0 (.0024)[1]	.023 (.0038)[1]	—	.015 (.00017)	—
16	.018 (.00071)[1]	.053 (.0016)	—	.0095 (.00090)[1]	.028 (.0)
21	.063 (.0011)	.080 (.0042)	—	.072 (.0054)	—
32	.10 (.0042)	.044 (.0015)	.043 (.0020)	.10 (.0036)	.0050 (.0040)[1]
35	.10 (.0090)	.081 (.0015)	—	.11 (.0014)	—
39	.012 (.00085)[1]	—	—	.026 (.0030)	—
42	.019 (.016)[1]	.015 (.0013)[1]	.067 (.0023)	.023 (.0066)	.061 (.0027)
44	.10 (.0050)	.030 (.0025)	—	.042 (.0018)	—
44	.016 (.00035)[1]	.010 (.0018)[1]	—	.084 (.00026)	—
47	.020 (.00092)[1]	0.0 (.0)[1]	—	.041 (.0018)	—
52	.11 (.0036)	0.0 (.0034)[1]	—	.083 (.0013)	—
61	.051 (.0025)	.0089 (.0058)[1]	—	.14 (.0067)	—
61	0.0 (.0027)[1]	—	—	.029 (.00045)	—
71NC	.042 (.0049)	0.0 (.0061)[1]	—	.055 (.0020)	—
77NC	.022 (.0062)[1]	0.0 (.0064)[1]	—	.016 (.0012)	—
84NC	.022 (.0015)[1]	0.0 (.00064)[1]	0.0 (.00016)[1]	.042 (.011)	.015 (.016)
104GB	.057 (.0018)	0.0 (.000099)[1]	—	.072 (.0018)	—
114GB	.039 (.0041)	0.0 (.0013)[1]	—	.024 (.0037)	—
125GB	.028 (.0034)[1]	0.0 (.0)[1]	—	.039 (.0017)	—
130GB	.021 (.0048)[1]	0.0 (.0014)[1]	0.0 (.0)[1]	.031 (.0018)	.044 (.0029)
$\bar{x}$ =	.038	.019	.022	.050	.032
σ =	.035	.026	.031	.034	.020
n =	23	21	5	23	6
median =	.022	.0089	0.0	.041	.028

[1]Below limit of detection.

TABLE 15. Comparison of 1980 to historical Lake Huron water lead concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965					< 5.	0.0	37	< 5.
1968[1]			37-39	2.7			37-39	2.7
1970	4.8	11.	13	2.	1.7	.80	21	1.-2.
1971					2.3	1.6	169	2.
1974	6.1	2.2	58	5.-7.	1.3	1.1	153	1.
1975[2]	.6	.2	10					
1976					1.0	0.0	18	1.
1977	.25	.25	43	.20	.23	.25	39	.10
1978	.21	.29	27	.10	.20	.26	27	.10
1980	.038	.035	23	.022	.019	.026	21	.0089

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.
[2]Nearshore waters; Poldoski *et al.* (1978).

remaining two stations (2.3 μg/L), suggesting Lake Superior water was diluting the North Channel water and that a local source of nickel was discharging to the North Channel.

Total nickel data exist for the years 1968, 1970, and 1974. Excluding 1968, total nickel median concentration is 1 μg/L for the years 1970 and 1974 (Table 17). The 1980 median concentration is 0.54 μg/L. The 1970 and 1974 data are of limited usefulness because they are at or near the limit of detection.

The 1980 dissolved nickel concentrations ranged between .19 and 3.4 μg/L (Table 16). As for the total, dissolved nickel concentrations in Georgian Bay (.66 μg/L) and in the North Channel (.98 μg/L) were considerably higher than those for the lake (.42 μg/L) or southern Lake Huron (.49 μg/L). No consistent concentration difference was found between .5 μm and .2 μm filtered water.

Dissolved nickel data are available for 1965, 1968, 1970, 1971, 1974, and 1976. Except for 1965 and 1968, the median concentration is 1 μg/L (Table 17). The 1980 median concentration is .49 μg/L. The 1970, 1974, and 1976 data are at or near the limit of detection and thus of limited usefulness. The difference between the 1980 concentration and 1970, 1971, 1974, and 1976 concentrations is small enough not to warrant discarding the historical data at this time.

Particulate nickel concentrations for 1980 varied between 0.0 and .13 μg/L (Table 16). Southern Lake Huron had the lowest median concentration (.0007 μg/L). The remainder of the lake had a median concentration of .027 μg/L. Georgian Bay had a median concentration of .042 μg/L, and the North Channel had a median concentration of .058 μg/L. This is a pattern similar to those observed for the total and filtered metal concentrations. Of the total nickel concentration, only 6% was as particulate matter.

Zinc

The 1980 total zinc concentrations ranged from .12 to .56 μg/L (Table 18). Georgian Bay (GB) (.19 μg/L) and southern Lake Huron (SLH) (.21 μg/L) median zinc concentrations were lower than those of central and northern Lake Huron (.29 μg/L). Those in the North Channel (NC) (.51 μg/L) were higher.

Total zinc data are available for 1968, 1970, 1974, 1976, 1977, and 1978. Excluding 1968, historical median total zinc concentrations range from 0.3 to 7 μg/L (Table 19). As the 1980 median concentration is nearly an order of magnitude or more lower (.29

TABLE 16. Nickel concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.51 (.068)	.73 (.0064)	—	.021 (.0030)	—
1SLH	.33 (.035)	.53 (.0050)	—	.025 (.0)	—
8SLH	.44 (.0081)	.40 (.030)	.43 (.0085)	0.0 (.0014)[1]	.0013 (.0024)
10SLH	.31 (.069)	.49 (.012)	—	.00070 (.0040)[1]	—
16	.59 (.040)	.42 (.0078)	.38 (.013)	.027 (.0020)	0.0 (.0028)[1]
21	.48 (.031)	.48 (.022)	—	.040 (.00092)	—
32	.38 (.025)	.19 (.014)	.33 (.0071)	.011 (.0034)	0.0 (.011)[1]
35	.54 (.021)	.45 (.056)	—	.034 (.0040)	—
39	.54 (.012)	.47 (.023)	—	0.0 (.0025)[1]	—
42	.41 (.0040)	.31 (.079)	.47 (.015)	.070 (.039)	0.0 (.00045)[1]
44	.54 (.042)	.41 (.028)	—	.022 (.0022)	—
44	.42 (.034)	.38 (.012)	—	.037 (.0024)	—
47	.45 (.051)	.28 (.018)	—	.044 (.0)	—
52	.58 (.0050)	.52 (.016)	—	.037 (.0030)	—
61	.74 (.016)	.50 (.032)	—	.025 (.00071)	—
61	.69 (.016)	.73 (.011)	—	.0040 (.0049)[1]	—
71NC	.96 (.032)	.62 (.015)	—	.086 (.0040)	—
77NC	2.1 (.14)	.98 (.15)	—	.058 (.0)	—
84NC	3.8 (.12)	2.8 (.17)	3.4 (.26)	.042 (.0059)	.13 (.0042)
104GB	.58 (.056)	.36 (.025)	—	.043 (.0036)	—
114GB	1.2 (.028)	.87 (.013)	—	.042 (.0099)	—
125GB	1.5 (.0058)	1.2 (.0071)	—	.074 (.0030)	—
130GB	1.0 (.12)	.66 (.072)	.63 (.049)	.021 (.0018)	.066 (.0074)
$\bar{x}$ =	.83	.64	.94	.033	.033
σ =	.77	.52	1.2	.023	.054
n =	23	23	6	23	6
median =	.54	.49	.43	.034	0.0

[1]Below limit of detection.

TABLE 17. Comparison of 1980 to historical Lake Huron water nickel concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965					< 5.	0.0	37	< 5.
1968[1]			37-39	4.			37-39	4.
1970	1.3	.49	12	1.	1.4	.67	11	1.
1971					1.5	.99	176	1.
1974	2.1	2.1	15	1.	2.5	1.7	156	1.
1976					2.3	2.5	18	1.
1980	.83	.77	23	.54	.64	.52	23	.49

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.

μg/L) than those of 1968, 1970, 1974, and 1976, these historical data should be discarded. A fair proportion of the 1977 and 1978 data is at or near the limit of detection.

For 1980, dissolved zinc concentrations varied from .026 to .81 μg/L (Table 18). The median concentration in southern Lake Huron (.085 μg/L) was roughly one-half that for the central and northern lake (.16 μg/L) and Georgian Bay (.13 μg/L). The North Channel had the highest median concentration (.27 μg/L). There was no discernible difference between the 0.5 μm and 0.2 μm filtered samples.

Historical dissolved zinc data exist for 1965, 1968, 1970, 1971, 1974, 1976, 1977, and 1978. A fair proportion of the 1977 and 1978 data is at or near the limit of detection. Excluding 1965 and 1968, median concentrations range from 1.0 to 7.0 μg/L (Table 19). The 1980 median concentration is .17 μg/L. Thus all historical data should be discarded.

In 1980, particulate zinc concentrations had a low of .065 μg/L and a high of .91 μg/L (Table 18). The median particulate zinc concentration in central and northern Lake Huron (.49 μg/L) was considerably higher than those for southern Lake Huron (.13 μg/L), the North Channel (.17 μg/L), and Georgian Bay (.18 μg/L). Sixty-six percent of the total zinc concentration was resident in the particulate matter.

Manganese

The 1980 total manganese concentrations varied from .25 to 1.2 μg/L (Table 20). Georgian Bay (GB) (.70 μg/L), the North Channel (NC) (.85 μg/L), and southern Lake Huron (SLH) (.73 μg/L) had median concentrations above that of central and northern Lake Huron (.64 μg/L).

Historical total manganese data exist for 1968, 1970, 1974, and 1975. Excluding 1968, the median concentrations vary between 1 and 2 μg/L (Table 21). The 1968 and 1970 data are at or near the limit of detection. All data compare favorably with the 1980 median concentration of .67 μg/L.

The 1980 dissolved manganese concentrations varied from .12 to .64 μg/L (Table 20). The median concentration for southern Lake Huron was .30 μg/L, for the northern and central portion of the lake was .26 μg/L, for the North Channel was .21 μg/L, and for Georgian Bay was .20 μg/L. There was no significant difference between the .5 μm and .2 μm filtered water results.

Historical dissolved manganese data are available for 1968, 1970, 1971, and 1974. Excluding 1968, their median concentrations range from 0.2 to 1 μg/L (Table 21). The 1968, 1970, and 1971 data are at or near the limit of detection and thus relatively useless for predicting trends. The 1980 median concentration is .28 μg/L. Thus the

TABLE 18. Zinc concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.21 (.071)	.085 (.043)[1]	—	.065 (.0021)[1]	—
1SLH	.25 (.096)	.17 (.045)[1]	—	.13 (.0035)[1]	—
8SLH	.20 (.030)	.026 (.0042)[1]	.19 (.173)	.34 (.044)	.35 (.014)
10SLH	.38 (.092)	.50 (.037)	—	.18 (.0035)	—
16	.40 (.16)	.56 (.039)	5.98 (.34)[2]	.33 (.0029)	.22 (.0056)
21	.24 (.044)	.14 (.13)[1]	—	.51 (.0)	—
32	.31 (.045)	.81 (.13)	.14 (.092)[1]	.49 (.015)	.27 (.0028)
35	.51 (.047)	.068 (.0076)[1]	—	.90 (.032)	—
39	.22 (.044)	.27 (.059)	—	.91 (.034)	—
42	.30 (.012)	.13 (.0099)[1]	.18 (.14)[1]	.39 (.0014)	2.13 (.11)[2]
44	.28 (.042)	.15 (.028)[1]	—	.19 (.0085)	—
44	.24 (.0021)	.46 (.072)	—	.32 (.0099)	—
47	.38 (.092)	.17 (.046)[1]	—	.75 (.0028)	—
52	.29 (.066)	.16 (.021)[1]	—	9.61 (.85)[2]	—
61	2.8 (.22)[2]	2.3 (.22)[2]	—	.058 (.0064)	—
61	.79 (.092)[2]	.25 (.047)[2]	—	.33 (.0)[2]	—
71NC	.51 (.055)	.27 (.031)	—	1.1 (.025)[2]	—
77NC	.32 (.012)	.24 (.075)	—	.17 (.0021)	—
84NC	.56 (.052)	.34 (.0)	.24 (.076)	.71 (.040)	.38 (.0030)
104GB	.12 (.014)	.13 (.035)[1]	—	.38 (.038)	—
114GB	.21 (.014)	.40 (.090)	—	.23 (.0078)	—
125GB	.19 (.013)	.12 (.052)[1]	—	.18 (.028)	—
130GB	.39 (.16)	.33 (.19)	.072 (.037)[1]	.13 (.0031)[1]	.33 (.0085)
$\bar{x}$ =	.31	.26	.16	.38	.31
σ =	.12	.20	.063	.26	.064
n =	21	21	5	19	5
median =	.29	.17	.18	.33	.33

[1]Below limit of detection.
[2]Result ignored for calculation of mean and median.

TABLE 19. Comparison of 1980 to historical Lake Huron water zinc concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1965					< 5.	0.0	37	< 5.
1968[1]			37-39	33.			37-39	33.
1970	4.4	2.8	12	4.	6.8	7.4	12	4.-6.
1971					7.3	4.8	174	6.-7.
1974[2]	5.0	2.4	67	3.-7.	5.1	2.4	68	1.-2.
1976[3]					2.4	.92	18	2.
1976	2.1	2.4	38	1.0	2.4	2.4	34	2.0
1977	.72	.56	43	.40	1.5	2.2	39	1.0
1978	.56	.45	27	.30	2.2	3.1	27	1.0
1980	.31	.12	21	.29	.26	.20	21	.17

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.
[2]Data > 10 μg/L were excluded.
[3]Nearshore waters; Poldoski *et al.* (1978).

1968 and 1970 data should be used with caution. The 1971 and 1974 data compare favorably to those of 1980.

In 1980, particulate manganese concentrations varied from .17 to 3 μg/L (Table 20). The median concentration in Georgian Bay was .59 μg/L and in the North Channel was 1 μg/L. These median concentrations were above those for southern Lake Huron (.45 μg/L) and the northern and central open lake (.35 μg/L). Of the total manganese concentration, 67% was associated with particulate matter (> .5 μm diameter).

Mercury

Total mercury 1980 concentrations in Lake Huron ranged between 0.0 and .35 μg/L (Table 22). Unfortunately, a large fraction of the samples had an undetectable concentration.

Historical total mercury data for the years 1971 and 1974 range from 0.05 to 1 μg/L (Table 23). The data of 1970, with a median of 1 μg/L, which appear to be at or near the limit of detection, should be discarded. The 1980 median concentration is .011 μg/L. All historical data are suspect. Both the 1980 and 1974 data are at or near the limit of detection.

Dissolved 1980 mercury concentrations ranged from 0.0 to .36 μg/L (Table 22). It is unfortunate that most of the samples had a concentration below the limit of detection.

Historical dissolved mercury concentrations are available for the years 1970, 1971, and 1974. Their medians range between 0.05 and 0.3 μg/L (Table 23). The 1980 median concentration is .0042 μg/L. All data for all years are of limited usefulness because they are at or near the limit of detection. An estimated 62% of the total mercury was associated with particulate matter.

Arsenic

In 1980, total arsenic concentrations ranged from .072 to .53 μg/L (Table 24). Georgian Bay (GB) (.12 μg/L) and the North Channel (NC) (.16 μg/L) median concentrations were lower than that for the remainder of the lake (.24 μg/L).

TABLE 20. Manganese concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.67 (.037)	.33 (.019)	—	.38 (.0072)	—
1SLH	.73 (.034)	.26 (.00071)	—	.72 (.0014)	—
8SLH	1.1 (.044)	.30 (.030)	.35 (.0064)	.45 (.0018)	1.5 (.0070)
10SLH	1.0 (.027)	.64 (.0042)	—	.50 (.0014)	—
16	.70 (.0041)	.30 (.0028)	.31 (.017)	.25 (.0080)	.84 (.0080)
21	1.2 (.014)	.16 (.011)	—	1.4 (.012)	—
32	.61 (.022)	.28 (.018)	.28 (.00071)	.41 (.0070)	.22 (.0067)
35	.82 (.019)	.28 (.026)	—	1.1 (.0010)	—
39	.65 (.016)	.30 (.021)	—	.21 (.020)	—
42	.64 (.043)	.31 (.0078)	.25 (.018)	.71 (.050)	.29 (.0080)
44	.62 (.018)	.22 (.0075)	—	.58 (.0021)	—
47	.67 (.063)	.14 (.023)	—	.35 (.026)	—
52	.55 (.030)	.32 (.011)	—	.29 (.0051)	—
61	.58 (.038)	.25 (.0090)	—	.18 (.0042)	—
61	.58 (.040)	.26 (.020)	—	.67 (.0071)	—
71NC	.25 (.0070)	.47 (.023)	—	3.0 (.023)	—
77NC	.85 (.043)	.12 (.0057)	—	.92 (.0060)	—
84NC	.96 (.038)	.21 (.0035)	.25 (.0014)	1.0 (.015)	1.1 (.0)
104GB	.85 (.078)	.12 (.028)	—	1.0 (.032)	—
114GB	.70 (.024)	.20 (.016)	—	.59 (.017)	—
125GB	1.1 (.047)	.30 (.00071)	—	1.4 (.021)	—
130GB	.56 (.032)	.29 (.014)	.30 (.013)	.42 (.0014)	.17 (.0025)
$\bar{x}$ =	.74	.27	.29	.73	.69
σ =	.22	.11	.038	.62	.56
n =	23	23	6	23	6
median =	.67	.28	.28	.58	.29

TABLE 21. Comparison of 1980 to historical Lake Huron water manganese concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1968[1]			37 39	< 1.			37 39	< 1.
1970	3.	5.4	12	1.	1.	0.0	4	1.
1971					.31	.33	167	.2
1974	3.2	3.6	111	2.	.43	.42	184	.2
1975[2]	1.3	.2	10					
1980	.74	.22	23	.67	.27	.11	23	.28

[1]Weiler and Chawla (1969); total and dissolved results were averaged together by the authors.
[2]Nearshore waters; Poldoski *et al.* (1978).

Total arsenic data exist for only 1974 and 1975. Their means range from 0.8 to 1 μg/L (Table 25). Some of the 1974 data were obtained under circumstances of a rather high (1 μg/L) limit of detection. The historical mean and median concentrations are higher than those of 1980, .25 and .21 μg/L respectively.

In 1980, dissolved arsenic concentrations ranged between 0.0 and .75 μg/L (Table 24). Twenty-two percent of the samples had undetectable concentrations. The Georgian Bay median concentration (.12 μg/L) was lower than those for the North Channel (.36 μg/L), southern Lake Huron (.23 μg/L), and northern and central Lake Huron (.27 μg/L). The 0.5 μm and .2 μm filtered results do not differ from one another.

Dissolved arsenic data exist only for 1974. The 1974 data have a median concentration of 0.4 μg/L (Table 25). The 1980 median concentration is .25 μg/L. The historical data are somewhat higher than those of 1980.

Particulate arsenic concentrations ranged from .00052 to .030 μg/L. The data are of limited usefulness because 61% of the samples had a concentration below the limit of detection. The median concentrations were highest for southern Lake Huron (.0097 μg/L) and Georgian Bay (.0082 μg/L). Those for the North Channel and northern and central Lake Huron were .0026 and .0066 μg/L, respectively. Only 3% of the total arsenic resided in the particulate matter.

Aluminum

For 1980, total aluminum concentrations varied between 2.5 and 26 μg/L (Table 26). In Georgian Bay (GB), the median concentration was 7.7 μg/L. This was lower than those for southern Lake Huron (SLH) (12 μg/L), the North Channel (NC) (9.6 μg/L), and northern and central Lake Huron (8.5 μg/L).

Dissolved aluminum concentrations ranged from .35 to 38 μg/L (Table 26). The median aluminum concentration was highest in southern Lake Huron (4 μg/L) and lowest in northern and central Lake Huron (2.2 μg/L). It was very similar for the North Channel (3.1 μg/L) and Georgian Bay (3 μg/L). Considerable difference in mean and median concentrations exist for the 0.5 and 0.2 μm filtered samples.

Historical total and dissolved aluminum data exist only for 1974. The median total and dissolved concentrations are 25 to 30 and < 20 μg/L, respectively (Table 27). These are of limited usefulness as they are at or near the limit of detection. The 1980 median concentration for total aluminum is 8.8 μg/L and for dissolved aluminum is 3.1 μg/L. The 1974 aluminum data appear to be too high.

Particulate aluminum concentrations varied between 2.9 and 81 μg/L. Median

TABLE 22. Mercury concentrations in Lake Huron water (μg/L).

Station	Total		Dissolved		Particulate	
			0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	0.0[1]		0.0[1]			
1SLH	0.0[1]		0.0[1]	N	N	N
8SLH	.0092		.36	O	O	O
10SLH	.097	(.011)	.0042[1]			
16	.097	(.0092)	0.0[1]	A	A	A
21	.0074[1]		.030 (.031)[1]	N	N	N
32	0.0[1]		0.0[1]	A	A	A
35	0.0[1]		.038[1]	L	L	L
39	0.0[1]		.088[1]	Y	Y	Y
42	.20		.036 (.092)[1]	S	S	S
44	0.0[1]		.14	E	E	E
44	.21		.25	S	S	S
47	.35	(.078)	.018[1]			
52	.15		.043[1]			
61	.10		.10[1]			
61	.013[1]		0.0[1]			
71NC	.011[1]		0.0[1]			
77NC	.017[1]		0.0[1]			
84NC	.099	(.056)	.035 (.044)[1]			
104GB	0.0[1]		0.0[1]			
114GB	.012	(.025)[1]	0.0[1]			
125GB	.0014	(.0096)[1]	0.0 (.039)[1]			
130GB	0.0	(.030)[1]	0.0 (.042)[1]			
$\bar{x}$ =	.060		.050			
σ =	.092		.090			
n =	23		23			
median =	.011		.0042			

[1]Below limit of detection.

TABLE 23. Comparison of 1980 to historical Lake Huron water mercury concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1970	1.	0.0	2	1.				
1970[1]					.17	.11	387-519	.2-.3
1971					.32	.45	178	.1-.3
1974	.053	.012	127	.05	.052	.0096	27	.05
1980	.060	.092	23	.011	.050	.090	23	.0042

[1]Chau and Saitoh (1973); 387 samples for calculating mean and standard deviation and 519 samples for determining the median concentration.

particulate aluminum concentrations were comparatively very high in southern Lake Huron (49 μg/L). Those in Georgian Bay were comparatively quite low (5.6 μg/L). Those of the North Channel and northern and central Lake Huron were 14 and 15 μg/L, respectively. Eighty-three percent of the total aluminum existed as particulate matter. This may account for the variability of analytical results.

Silver

Total silver concentrations ranged between .00019 and .042 μg/L in 1980 (Table 28). Median concentration was highest in southern Lake Huron (SLH) (.017 μg/L) and lowest in the North Channel (NC) (.00080 μg/L). Georgian Bay (GB) (.0087 μg/L) and the lake (.0089 μg/L) had very similar silver median concentrations. Of all samples, 22% had an undetectable concentration. No historical data could be found.

Dissolved silver concentrations ranged from 0.0 to .016 μg/L (Table 28). Nearly 35% of the samples had an undetectable concentration. Median concentration was highest in the North Channel (.011 μg/L). Southern Lake Huron (.0054 μg/L), Georgian Bay (.0058 μg/L), and northern and central Lake Huron (.0054 μg/L) all had very similar median concentrations. No consistent difference was found between 0.5 μm and 0.2 μm filtered water. No historical data could be found.

Particulate silver concentrations varied from .00066 to .0031 μg/L (Table 28). Median concentrations were the same and highest in the North Channel (.017 μg/L) and Georgian Bay (.017 μg/L). They were similar for southern Lake Huron (.0010 μg/L) and northern and central Lake Huron (.00093 μg/L). On the average, only 18% of the total silver in water was associated with particulate matter.

Vanadium

In 1980, total vanadium concentrations varied from .10 to 1.1 μg/L (Table 29). Southern Lake Huron (SLH) (.22 μg/L) and northern and central Lake Huron (.21 μg/L) had similar median concentrations. Georgian Bay (GB) and the North Channel (NC) had median concentrations of .16 and .33 μg/L, respectively. Historical data exist only for 1971. The median concentration for 1971 is .1 μg/L compared to .22 μg/L for 1980 (Table 30).

Dissolved vanadium concentrations ranged from .087 to .92 μg/L (Table 29). Median concentration was highest in the North Channel (.30 μg/L) and lowest in southern Lake Huron (.12 μg/L). Median concentrations in Georgian Bay and northern and central Lake Huron were .22 and .24 μg/L, respectively. No historical data were found.

TABLE 24. Arsenic concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.17 (.0035)	.23 (.0052)	—	.011 (.00078)[1]	—
1SLH	.27 (.0035)	.059 (.0027)	—	.0097 (.0063)[1]	—
8SLH	.31 (.0016)	.24 (.023)	0.0 (.0)[1]	.0086 (.00035)	.030 (.0)
10SLH	.27 (.023)	.25 (.011)	—	.013 (.0)	—
16	.21 (.0084)	.21 (.0032)	.29 (.0016)	.0019 (.00077)[1]	.014 (.0069)[1]
21	.27 (.0016)	.34 (.013)	—	.0052 (.00055)[1]	—
32	.53 (.016)	.47 (.018)	.50 (.0014)	.012 (.00085)	.0056 (.0031)[1]
35	.28 (.0026)	.31 (.047)	—	.0020 (.0)[1]	—
39	.30 (.019)	.27 (.0064)	—	.0087 (.00050)	—
42	.49 (.048)	.31 (.028)	.40 (.066)	.0066 (.0044)[1]	.0060 (.0028)[1]
44	.37 (.0)	.58 (.0042)	—	.011 (.0027)[1]	—
44	.24 (.0058)	0.0 (.0)[1]	—	.012 (.00039)	—
47	.12 (.0)	.28 (.011)	—	.0098 (.0014)	—
52	.41 (.011)	0.0 (.0)[1]	—	.0011 (.00072)[1]	—
61	.20 (.027)	0.0 (.0)[1]	—	.0062 (.00058)[1]	—
61	.21 (.0035)	0.0 (.0)[1]	—	.0078 (.00089)	—
71NC	.18 (.0038)	1.75 (.099)	—	.00052 (.00091)[1]	—
77NC	.14 (.018)	.36 (.018)	—	.0026 (.0026)[1]	—
84NC	.16 (.040)	.12 (.0092)	.14 (.015)	.015 (.013)[1]	.0070 (.0023)[1]
104GB	.14 (.0078)	0.0 (.0)[1]	—	.017 (.00734)[1]	—
114GB	.072 (.016)	.27 (.099)	—	.0045 (.0045)[1]	—
125GB	.21 (.020)	.12 (.0071)	—	.0098 (.00032)	—
130GB	.12 (.0064)	.26 (.031)	.41 (.040)	.0082 (.00034)	.0043 (.00086)[1]
$\bar{x}$ =	.25	.24	.29	.0080	.011
σ =	.12	.19	.19	.0046	.0099
n =	23	23	6	23	6
median =	.21	.25	.29	.0086	.0060

[1]Below limit of detection.

TABLE 25. Comparison of 1980 to historical Lake Huron water arsenic concentrations (μg/L).

Year	Total				Dissolved			
	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1974	< 1.	0.0	47	< 1.	.50	.35	89	.4
1975[1]	.8	.1	10					
1980	.25	.12	23	.21	.24	.19	23	.25

[1]Nearshore waters: Poldoski *et al.* (1978).

Particulate vanadium concentrations ranged from .0026 to .083 μg/L (Table 29). Unfortunately, 26% of the samples had an undetectable concentration. Median concentration was highest in the North Channel (.023 μg/L). It was lowest in central and northern Lake Huron (.010 μg/L). Southern Lake Huron and Georgian Bay had concentrations of .017 and .014 μg/L, respectively. An average of 6% of the total vanadium existed as particulate matter.

Selenium

For 1980, total selenium concentrations varied between .16 and 1.2 μg/L (Table 31). Median concentrations for southern Lake Huron (SLH) (.41 μg/L), northern and central Lake Huron (.43 μg/L), the North Channel (NC) (.41 μg/L), and Georgian Bay (GB) (.48 μg/L) were quite similar to one another. Historical data exist only for 1974 and are at the limit of detection. The median for 1974 is < 1 μg/L and that for 1980 is .48 μg/L (Table 32).

Dissolved selenium concentrations varied from .096 to 1 μg/L (Table 31). Median concentration was highest for Georgian Bay (.77 μg/L). This was followed by northern and central Lake Huron (.58 μg/L). Southern Lake Huron (.41 μg/L) and the North Channel (.37 μg/L) had very similar median concentrations. The median concentration for 1980 (.48 μg/L) is considerably higher than that of .1 μg/L for 1974 (Table 32). No concentration difference was noted between the 0.2 and 0.5 μm filtered samples.

All particulate results were below the limit of detection and equalled the analytical blank. Therefore, 0% of the total selenium exists as particulate matter.

TABLE 26. Aluminum concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	12. (.35)	13. (1.5)	—	44. (.46)	—
1SLH	17. (1.1)	4.0 (.63)	—	49. (4.2)	—
8SLH	6.5 (.29)	2.8 (.014)	5.5 (0.0)	7.2 (.28)	81. (5.6)
10SLH	21. (1.4)	16. (.21)	—	57. (.95)	—
16	10. (.73)	1.2 (.16)	1.1 (.056)	21. (.28)	18. (1.1)
21	6.4 (.93)	38. (.21)	—	46. (3.1)	—
32	4.6 (.18)	3.0 (.17)	.35 (.056)	15. (.42)	20. (1.5)
35	20. (1.1)	5.6 (.32)	—	10. (.50)	—
39	18. (1.7)	1.9 (.22)	—	7.1 (.16)	—
42	3.8 (1.0)	1.2 (.48)	3.2 (1.1)	23. (2.2)	24. (1.2)
44	6.9 (1.7)	5.0 (5.4)	—	25. (1.2)	—
44	8.8 (2.5)	2.2 (.23)	—	24. (.21)	—
47	12. (.42)	.86 (.16)	—	12. (.21)	—
52	2.5 (.44)	.66 (.16)	—	3.6 (.050)	—
61	26. (.21)	6.6 (.51)	—	13. (.21)	—
61	8.5 (.95)	8.3 (1.6)	—	18. (.28)	—
71NC	21. (1.2)	5.0 (.57)	—	57. (1.6)	—
77NC	7.2 (1.3)	1.3 (.12)	—	14. (1.3)	—
84NC	9.6 (.64)	3.1 (.078)	5.8 (.66)	9.5 (.071)	13. (1.3)
104GB	12. (.56)	3.0 (.064)	—	14. (1.1)	—
114GB	8.6 (.52)	3.8 (.23)	—	2.9 (.092)[1]	—
125GB	6.8 (.68)	1.4 (.042)	—	6.9 (1.2)	—
130GB	7.7 (.11)	8.9 (1.8)	1.8 (.23)	5.6 (.092)	7.7 (.24)
$\bar{x}$ =	11.	6.0	3.0	24.	27.
σ =	6.4	8.0	2.3	20.	27.
n =	23	23	6	23	6
median =	8.8	3.1	1.8	15.	18.

[1]Below limit of detection.

TABLE 27. Comparison of 1980 to historical Lake Huron water aluminum concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1974	37.	12.	9	25.–30.	< 20.	0.0	23	< 20.
1980	11.	6.4	23	8.8	6.0	8.0	23	3.1

TABLE 28. Silver concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.024 (.0012)	.017 (.00072)	—	.00068 (.000039)	—
1SLH	.017 (.0012)	.015 (.00114)	—	.0011 (.00014)	—
8SHL	.022 (.0016)	.0046 (.0055)[1]	.016 (.0018)	.0013 (.0)	.0013 (.00047)
10SLH	.013 (.0013)	.0054 (.0015)	—	.0010 (.000021)	—
16	.014 (.00057)	.0034 (.00042)	.0073 (.0023)	.00090 (.000020)	.0010 (.000084)
21	.0089 (.00053)	.0046 (.00085)	—	.00088 (.000020)	—
32	.011 (.0012)	.0035 (.00023)	.0062 (.00067)	.00068 (.000076)	.0021 (.0)
35	.00037 (.00025)[1]	.00012 (.00020)[1]	—	.00093 (.000042)	—
39	.0044 (.0042)[1]	.0012 (.0015)[1]	—	.0031 (.000076)	—
42	.0090 (.0054)	.0020 (.0023)[1]	0.0 (.0)[1]	.0016 (.000071)	.0018 (.00026)
44	.010 (.00021)	.0079 (.0023)	—	.00067 (.000057)	—
44	.0072 (.0011)	.0059 (.0027)	—	.0013 (.00011)	—
47	.0051 (.0014)	.012 (.013)[1]	—	.0015 (.0)	—
52	.00069 (.0012)[1]	.0047 (.00057)[1]	—	.00090 (.000020)	—
61	.019 (.00071)	.0088 (.0016)	—	.0013 (.000042)	—
61	.042 (.042)	.0077 (.00040)	—	.0012 (.000055)	—
71NC	.0053 (.00064)	.013 (.023)[1]	—	.0018 (.000099)	—
77NC	.00080 (.0014)[1]	.0042 (.0010)[1]	—	.00090 (.0)	—
84NC	.00019 (.00038)[1]	.011 (.0043)	.0058 (.00023)	.0017 (.00028)	.0015 (.000042)
104GB	.014 (.0026)	.016 (.00014)	—	.0021 (.00029)	—
114GB	.011 (.0057)	.0058 (.000057)	—	.0017 (.0)	—
125GB	.0087 (.0047)	.0060 (.00038)	—	.0019 (.00024)	—
130GB	.0034 (.0018)	.0058 (.0014)	.0057 (.0032)	.0013 (.00027)	.0022 (.0)
$\bar{x}$ =	.011	.0072	.0068	.0013	.0016
σ =	.0096	.0047	.0052	.00057	.00046
n =	23	23	6	23	6
median =	.0090	.0058	.0058	.0013	.0015

[1]Below limit of detection.

TABLE 29. Vanadium concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.41 (.037)	.14 (.0028)	—	.016 (.0049)	—
1SLH	.23 (.020)	.12 (.016)	—	.022 (.0018)	—
8SLH	.19 (.013)	.11 (.028)	.087 (.0071)	.025 (.0038)	.026 (.0019)
10SLH	.22 (.047)	.16 (.0050)	—	.017 (.0013)	—
16	1.1 (.17)	.40 (.0014)	.92 (.12)	.0087 (.0035)[1]	.013 (.0012)[1]
21	.18 (.011)	.24 (.015)	—	.015 (.0017)	—
32	.21 (.0099)	.16 (.022)	No data	.013 (.00057)	.011 (.00078)[1]
35	.13 (.0078)	.50 (.0035)	—	.012 (.00060)	—
39	.18 (.035)	.48 (.014)	—	.010 (.0010)	—
42	.33 (.017)	.14 (.050)	.24 (.0092)	.013 (.00064)[1]	.012 (.0029)[1]
44	.27 (.0028)	.20 (.0099)	—	.0091 (.00099)[1]	—
44	.14 (.0057)	.16 (.0071)	—	.0081 (.00040)[1]	—
47	.32 (.040)	.60 (.28)	—	.0079 (.00061)[1]	—
52	.36 (.0085)	.26 (.014)	—	.0080 (.00051)	—
61	.21 (.024)	.24 (.0099)	—	.016 (.00028)	—
61	.60 (.10)	.24 (.17)	—	.014 (.00050)	—
71NC	.33 (.012)	.34 (.16)	—	.083 (.0046)	—
77NC	.55 (.15)	.30 (.0085)	—	.020 (.0034)	—
84NC	.12 (.047)	.26 (.014)	No data	.023 (.0013)	.012 (.0013)[1]
104GB	.17 (.0)	.22 (.0064)	—	.026 (.00035)	—
114GB	.25 (.036)	.38 (.033)	—	.0026 (.0)[1]	—
125GB	.10 (.028)	.56 (.16)	—	.014 (.0)	—
130GB	.16 (.018)	.14 (.050)	.36 (.044)	.016 (.00078)	.0074 (.0020)[1]
$\bar{x}$ =	.29	.28	.40	.017	.014
σ =	.22	.15	.36	.015	.0064
n =	23	23	4	23	6
median =	.22	.24	.24	.014	.012

[1]Below limit of detection.

TABLE 30. Comparison of 1980 to historical Lake Huron water vanadium concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1971	.31	.24	37	.1				
1980	.29	.22	23	.22	.28	.15	23	.24

TABLE 31. Selenium concentrations in Lake Huron water (μg/L).

Station	Total	Dissolved		Particulate	
		0.5 μm Filtered	0.2 μm Filtered	> .5 μm	> .2 μm
1SLH	.16 (.0038)	.41 (.016)	—		
1SLH	.41 (.0027)	.096 (.0024)	—	N	N
8SLH	1.2 (.072)	.44 (.017)	.77 (.034)	O	O
10SLH	.86 (.031)	.45 (.028)	—	T	T
16	.34 (.024)	.43 (.026)	.53 (.022)		
21	.48 (.0062)	.58 (.022)	—	D	D
32	.62 (.036)	.42 (.0024)	.46 (.0091)	E	E
35	.40 (.0027)	.67 (.015)	—	T	T
39	.39 (.012)	.58 (.044)	—	E	E
42	.53 (.0058)	1.0 (.021)	.67 (.046)	C	C
44	.43 (.012)	.48 (.0)	—	T	T
44	.40 (.031)	.32 (.0091)	—	A	A
47	.53 (.025)	.58 (.013)	—	B	B
52	.53 (.015)	.67 (.10)	—	L	L
61	.42 (.0025)	.58 (.031)	—	E	E
61	.58 (.045)	.53 (.053)	—		
71NC	.48 (.019)	.40 (.031)	—		
77NC	.36 (.053)	.24 (.0077)	—		
84NC	.41 (.026)	.37 (.0077)	.44 (.012)		
104GB	.53 (.024)	.37 (.077)	—		
114GB	.62 (.017)	.77 (.017)	—		
125GB	.48 (.026)	.77 (.053)	—		
130GB	.46 (.031)	.77 (.031)	.38 (.037)		
$\bar{x}$ =	.50	.52	.54		
σ =	.20	.20	.15		
n =	23	23	6		
median =	.48	.48	.46		

TABLE 32. Comparison of 1980 to historical Lake Huron water selenium concentrations (μg/L).

	Total				Dissolved			
Year	Mean	Std. Dev.	N	Median	Mean	Std. Dev.	N	Median
1974	< 1.	0.0	22	< 1.	.12	.040	61	.1
1980	.50	.20	23	.48	.52	.20	23	.48

SUMMARY

During analysis of the 1980 lake water samples, many results were unexpectedly lower than the existing historical data. Instrumentation and methodology have improved sufficiently to permit the recognition of obviously contaminated samples. This was not always possible in the past. The historical data for total and dissolved cadmium, lead, zinc, and probably mercury are poor. Historical data for total and dissolved copper, nickel, mercury, aluminum, and selenium, and total chromium and arsenic are questionable. Though few in number for some elements, good data exist for dissolved chromium, total and dissolved manganese and iron, dissolved arsenic, and total vanadium. Historical data could not be found for total silver, dissolved silver, and dissolved vanadium.

Compared to other regions of the lake during 1980, southern Lake Huron had the highest concentrations of iron and aluminum. It had the lowest concentrations of copper, chromium, lead, zinc, and perhaps nickel. The North Channel had relatively elevated concentrations of copper, nickel, manganese, and vanadium. Georgian Bay had the highest selenium and lowest iron, arsenic, and aluminum concentrations.

For 1980, median concentrations of each metal as well as its relative amount associated with particulate matter are summarized in Table 33. The amount of particulate matter present has a large impact upon measured total concentrations of aluminum, mercury, manganese, zinc, lead, cadmium, and iron. It has a small but important impact on total concentrations of silver, chromium, and copper. Particulate matter is relatively unimportant to measured total concentrations of selenium, vanadium, arsenic, and nickel.

TABLE 33. Summary of 1980 Lake Huron median trace metal concentrations in water and the partitioning of trace metals between the dissolved and particulate fractions.

Element	Total (μg/L)	Dissolved (μg/L) < .5 μm	Particulate (μg/L) > .5 μm	Particulate / Particulate + Dissolved
Fe	4.8	.80	6.4	.89
Cd	.015	0.	.012	1.00
Cu	.40	.28	.12	.30
Cr	.13	.11	.017	.13
Pb	.022	.0089	.041	.82
Ni	.54	.49	.034	.06
Zn	.29	.17	.33	.66
Mn	.67	.28	.58	.67
Hg	.011	.0042	—	.62
As	.21	.25	.0086	.03
Al	8.8	3.1	15.	.83
Ag	.0090	.0058	.0013	.18
V	.22	.24	.014	.06
Se	.48	.48	0.	.00

LITERATURE CITED

Chau, Y. K., and H. Saitoh. 1973. Mercury in the international Great Lakes. In *Proc. 16th Conf. Great Lakes Res.*, pp. 221–232. Internat. Assoc. Great Lakes Res.

Hoel, P. G. 1967. *Elementary Statistics.* New York: John Wiley & Sons. 351 pp.

International Joint Commission. 1977. *The waters of Lake Huron and Lake Superior, Vol. II. Lake Huron, Georgian Bay, and the North Channel.* Upper Lakes Reference Group. 743 pp.

Perkin-Elmer. 1977. *Analytical methods for atomic absorption spectroscopy using the HGA graphite furnace.* Perkin-Elmer Corporation, Norwalk, Conn.

Poldoski, J. E., E. N. Leonard, J. T. Fiandt, L. E. Anderson, G. F. Olson, and G. E. Glass. 1978. Factors in the determination of selected trace elements in near-shore U.S. waters of Lakes Superior and Huron. *J. Great Lakes Res.* 4:206–215.

USEPA. 1979. *Methods for chemical analysis of water and wastes.* EPA-600 4-79-020. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Weiler, R. R., V. K. Chawla. 1969. Dissolved mineral quality of the Great Lakes waters. In *Proc. 12th Conf. Great Lakes Res.*, pp. 801–818. Internat. Assoc. Great Lakes Res.